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(54) DEVELOPING DEVICE, AND IMAGE FORMING APPARATUS PROVIDED WITH THE SAME

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G03G 15/09 (2006.01)
G03G 15/08 (2006.01)

(52) **U.S. Cl.**
CPC ***G03G 15/0907*** (2013.01); ***G03G 15/0818*** (2013.01)

(58) **Field of Classification Search**
CPC G03G 15/0907; G03G 15/0806; G03G 15/0818
USPC 399/279, 286; 492/18, 53, 56
See application file for complete search history.

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(57) **ABSTRACT**

A developing device supplies a developer to a photosensitive drum, which has a cylindrical shape, and is rotatable around an axis thereof for forming an electrostatic latent image on the circumferential surface thereof. The developing device is provided with a developing roller. The developing roller is disposed to face the photosensitive drum, and has a cylindrical shape. The developing roller is rotatable around an axis thereof for carrying a developer on the circumferential surface thereof. The developing roller is provided with a small diameter portion. The small diameter portion is a part of the circumferential surface of the developing roller. The small diameter portion extends from an axial end of the developing roller axially inward by a predetermined length, and has an outer diameter smaller than an axially middle portion of the developing roller.

10 Claims, 9 Drawing Sheets

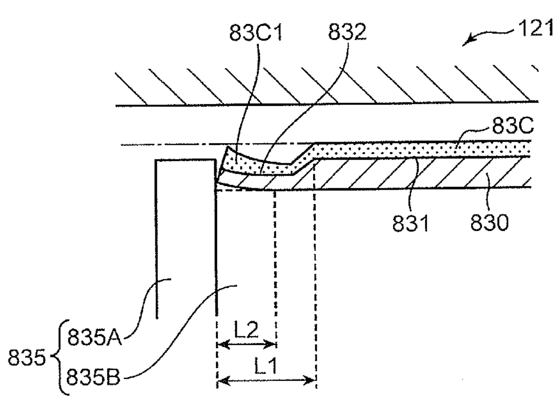
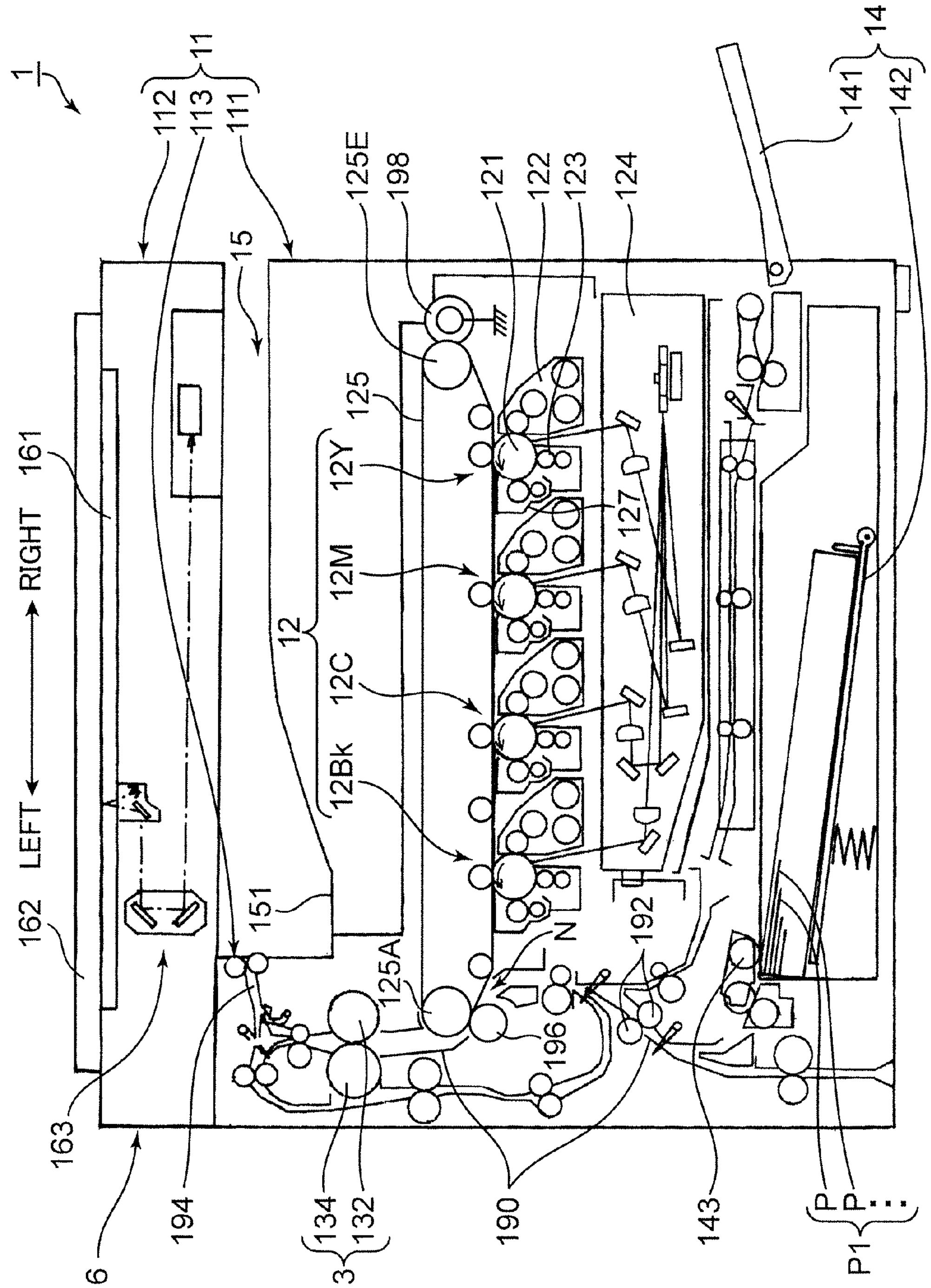
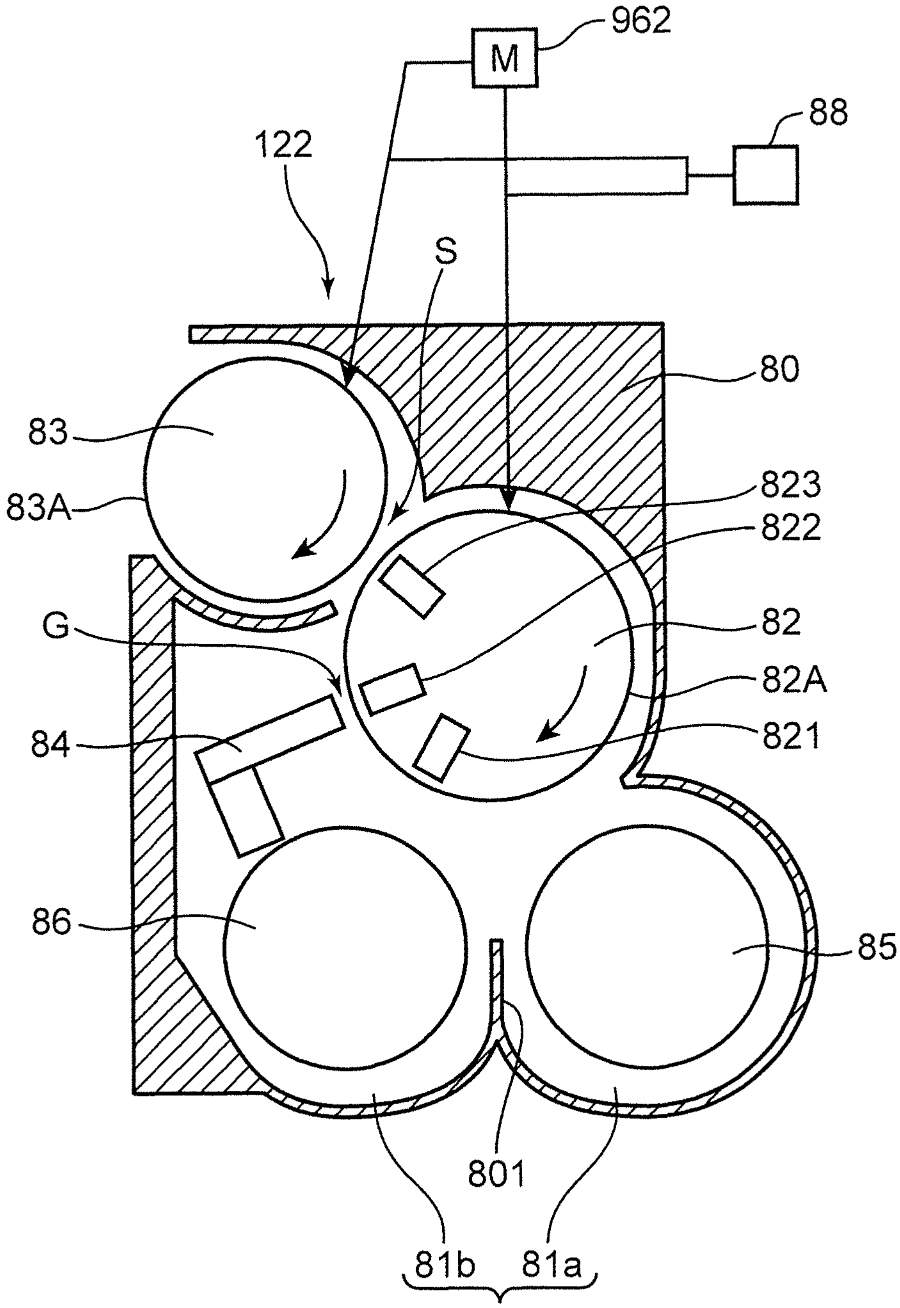


FIG.1



1
LEFT
RIGHT
11
111
112
113
12
12Y
12M
12C
12Bk
121
122
123
124
125
125A
125E
127
13
132
134
14
141
142
143
15
151
16
161
162
163
190
192
194
196
198
N
P1
P
P

FIG.2



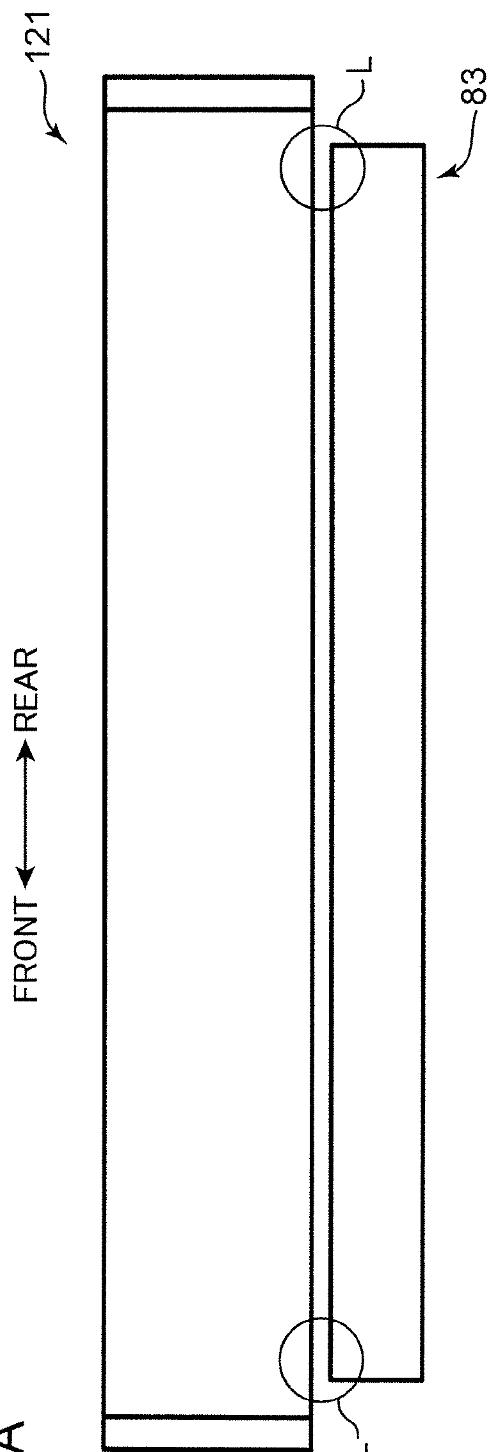


FIG.3A

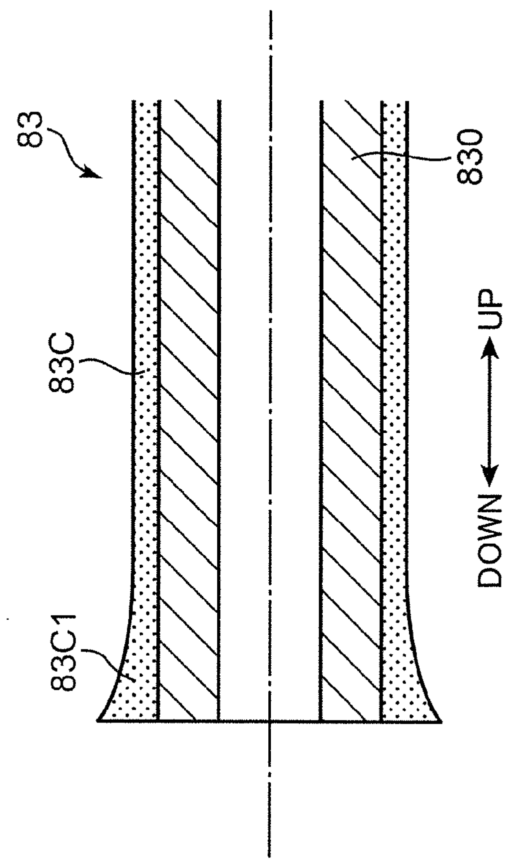


FIG.3B

FIG.4B

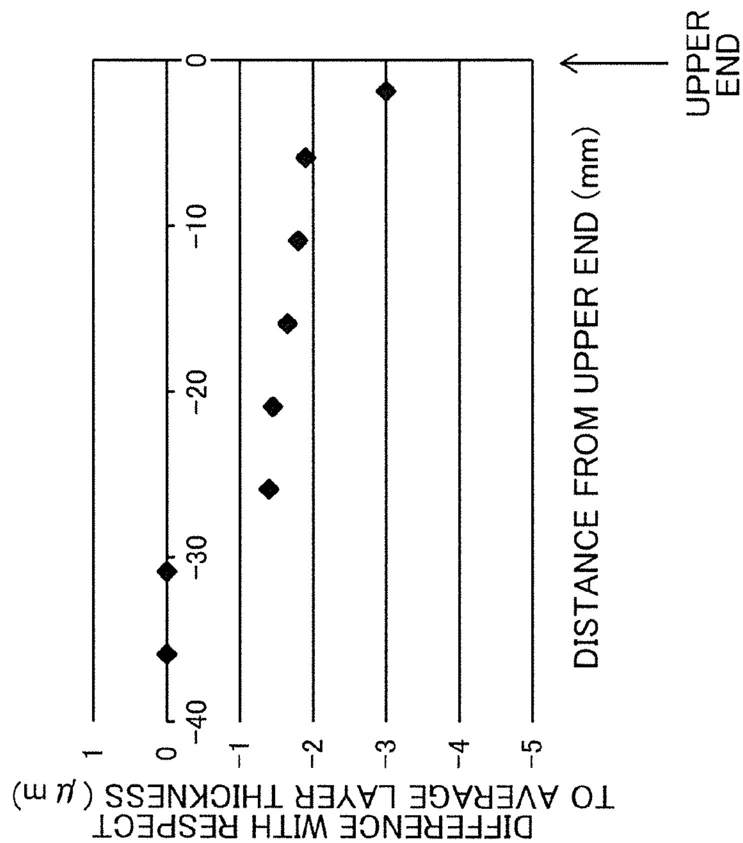

DIFFERENCE WITH RESPECT TO AVERAGE LAYER THICKNESS (μm)
1
0
−1
−2
−3
−4
−5
−40
−30
−20
−10
0
DISTANCE FROM UPPER END (mm)
UPPER END

FIG.4A

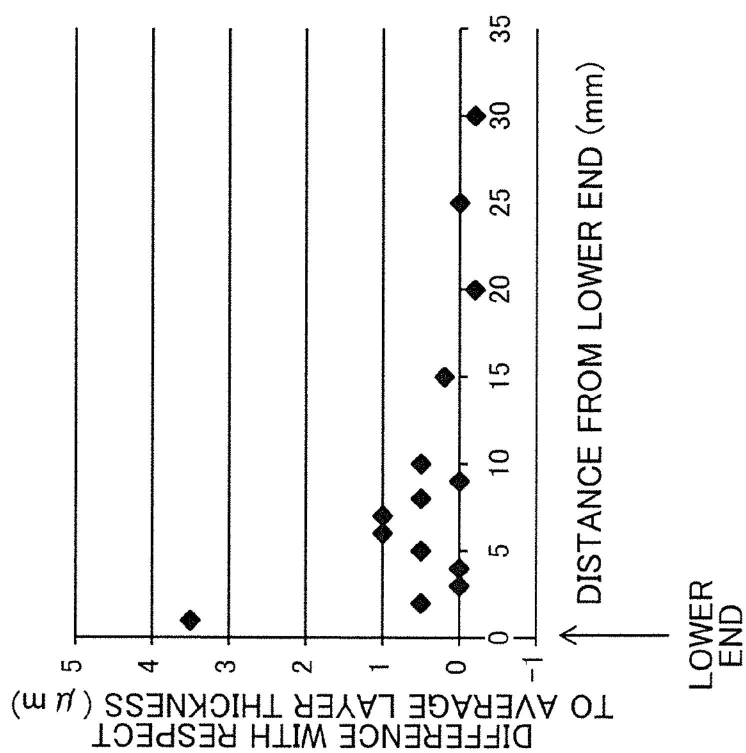

DIFFERENCE WITH RESPECT TO AVERAGE LAYER THICKNESS (μm)
5
4
3
2
1
0
−1
0
5
10
15
20
25
30
35
DISTANCE FROM LOWER END (mm)
LOWER END

FIG.5

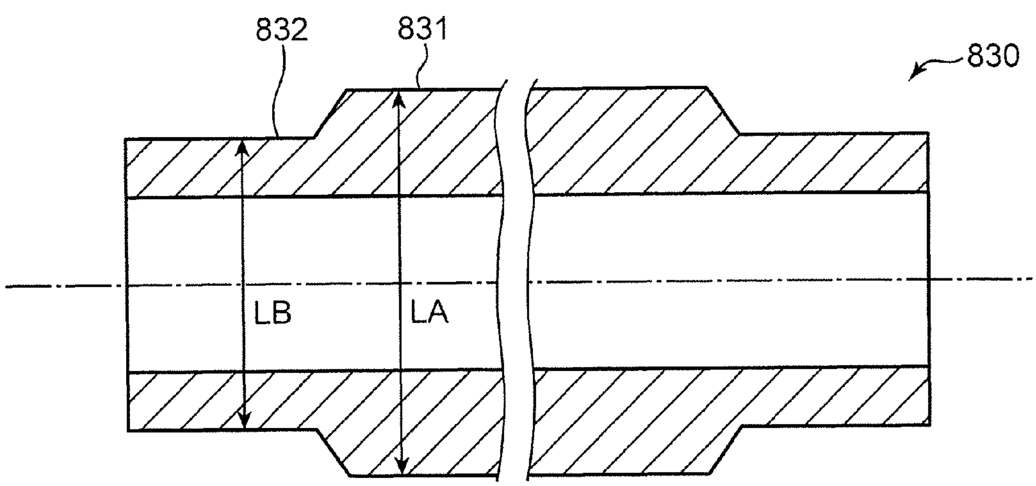


FIG.6B

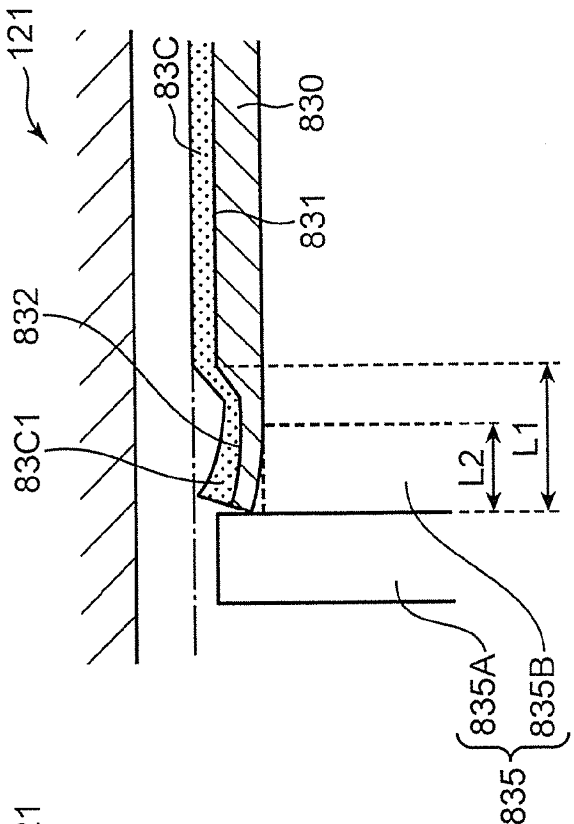


FIG.6A
(PRIOR ART)

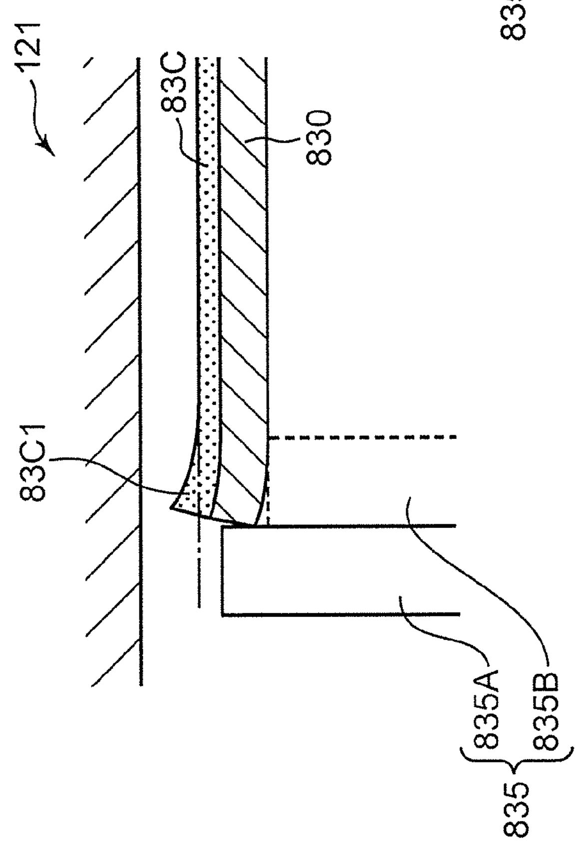


FIG.7

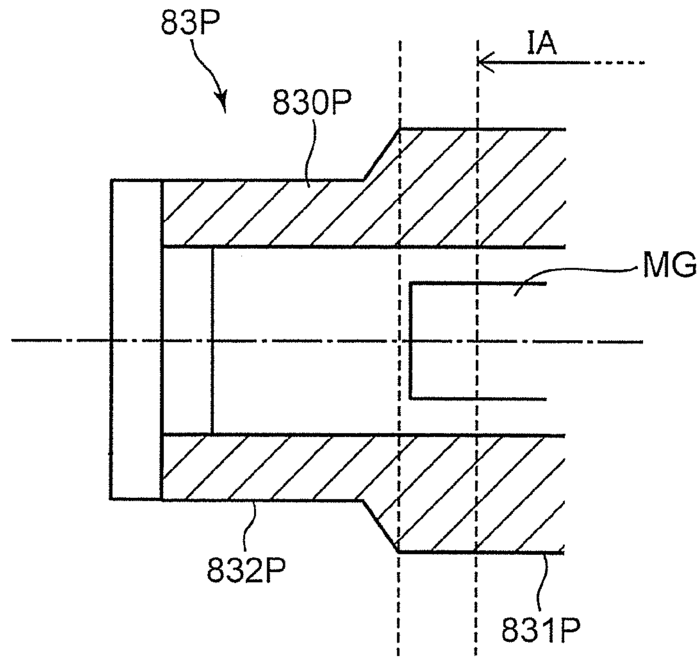

83P
830P
IA
MG
832P
831P

FIG.8

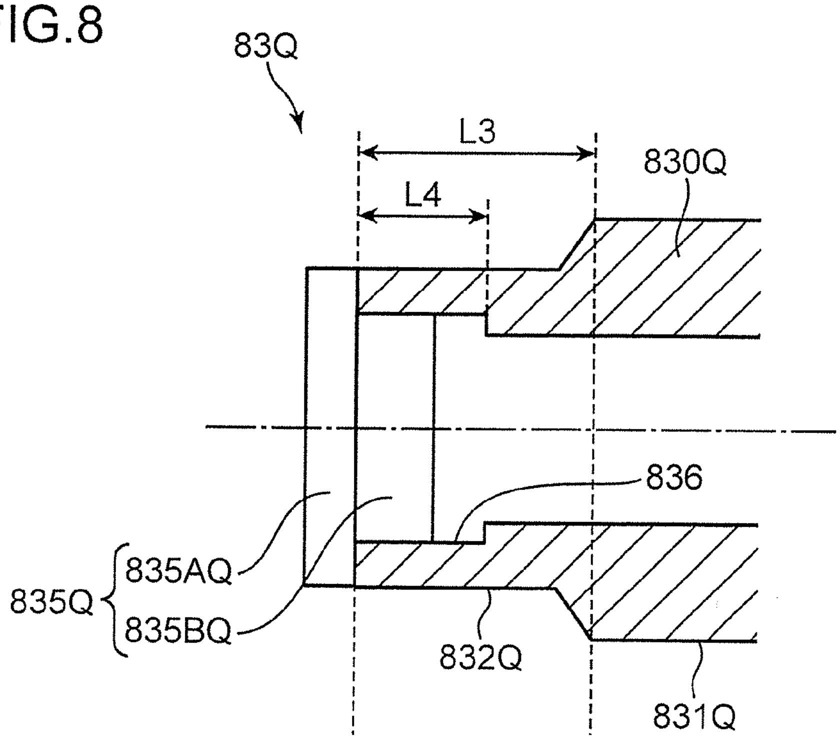
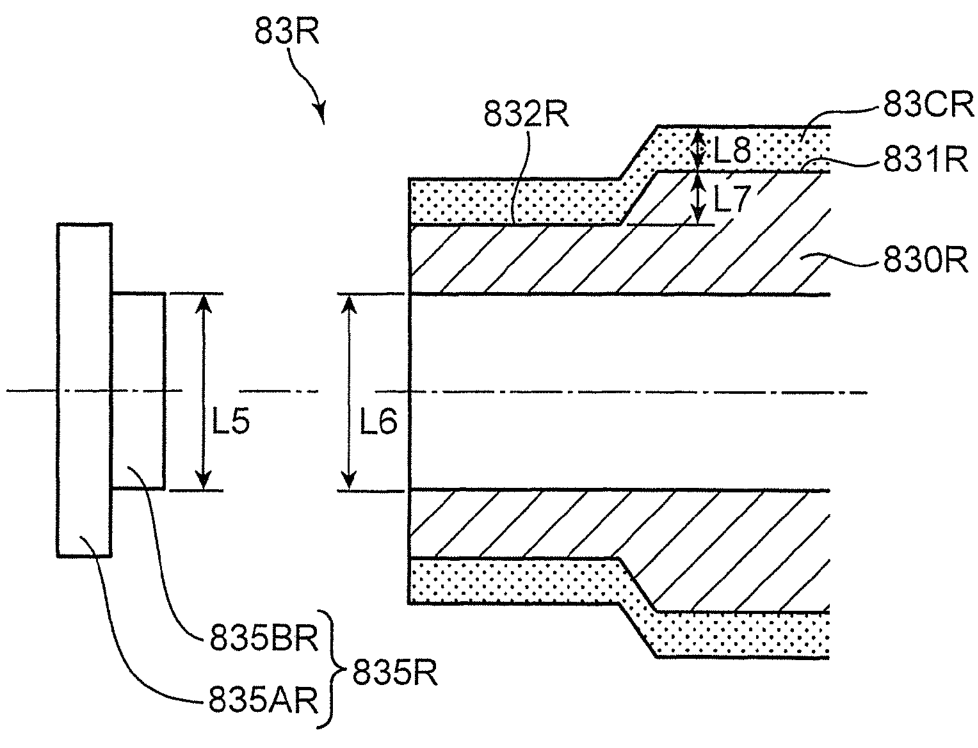

83Q
L3
L4
830Q
836
835Q
835AQ
835BQ
832Q
831Q

FIG.9



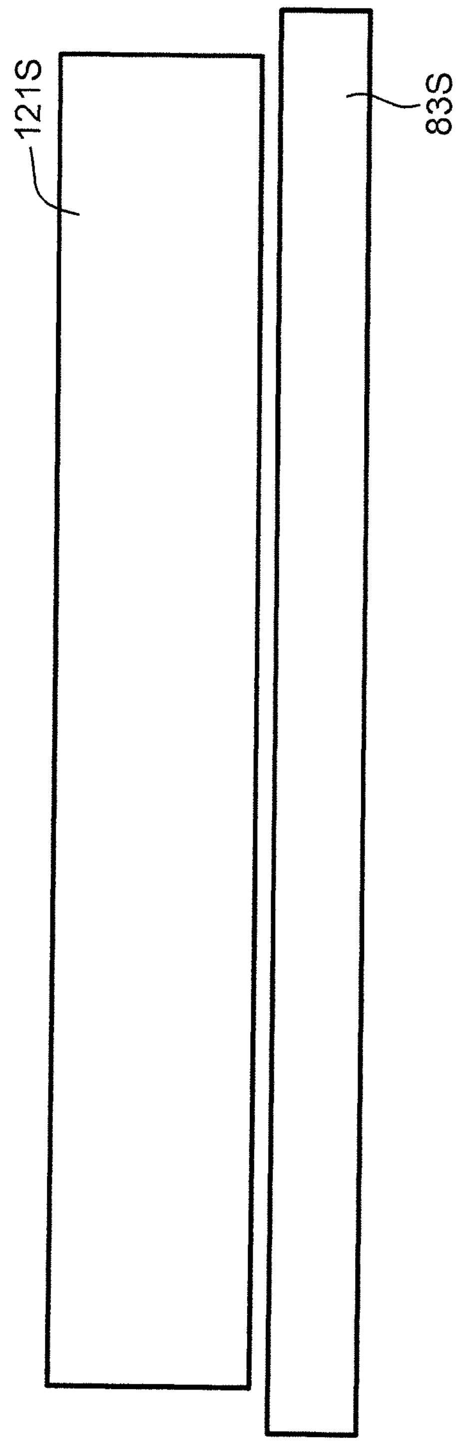


FIG.10A

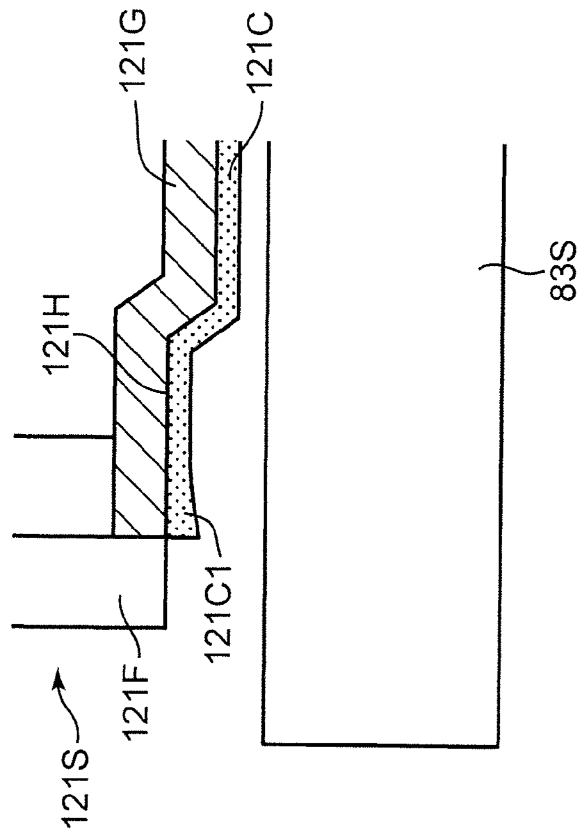


FIG.10B

DEVELOPING DEVICE, AND IMAGE FORMING APPARATUS PROVIDED WITH THE SAME

This application is based on Japanese Patent Application No. 2014-082587 filed on Apr. 14, 2014, the contents of which are hereby incorporated by reference.

BACKGROUND

The present disclosure relates to a developing device, and an image forming apparatus provided with the same.

In an image forming apparatus using an electrophotography method such as a copying machine, a printer, and a facsimile machine, a developing device supplies toner to an electrostatic latent image formed on a photosensitive drum, and the electrostatic latent image is developed to form a toner image on the photosensitive drum. As one of the methods for performing the developing operation, there is known a touch-down developing method, in which a two-component developer containing non-magnetic toner and magnetic carriers is used. In this configuration, a two-component developer layer (so-called magnetic brush layer) is formed on a magnetic roller. Toner is moved from the two-component developer layer to a developing roller to carry a toner layer. Conventionally, there is known a technique, in which a resin layer is formed on the surface of a developing roller. Further, there is known an immersion process (a dip process or a dipping process) of immersing a raw pipe of a developing roller in a resin solution in which a resin material is dissolved in advance in order to manufacture the developing roller.

SUMMARY

A developing device according to an aspect of the present disclosure supplies a developer to a photosensitive drum, which has a cylindrical shape, and is rotatable around an axis thereof for forming an electrostatic latent image on the circumferential surface thereof. The developing device is provided with a developing roller. The developing roller is disposed to face the photosensitive drum, and has a cylindrical shape. The developing roller is rotatable around an axis thereof for carrying a developer on the circumferential surface thereof. The developing roller is provided with a small diameter portion. The small diameter portion is a part of the circumferential surface of the developing roller. The small diameter portion extends from an axial end of the developing roller axially inward by a predetermined length, and has an outer diameter smaller than an axially middle portion of the developing roller.

An image forming apparatus according to another aspect of the present disclosure is provided with the developing device having the aforementioned configuration, and a photosensitive drum. A developer is supplied from the developing roller to the photosensitive drum.

These and other objects, features and advantages of the present disclosure will become more apparent upon reading the following detailed description along with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view illustrating an inner structure of an image forming apparatus embodying the present disclosure.

FIG. **2** is a sectional view of a developing device in the embodiment of the present disclosure.

FIG. **3**A is a schematic diagram illustrating a relationship between the axial length of a photosensitive drum and the axial length of a developing roller in a first embodiment of the present disclosure.

FIG. **3**B is a schematic sectional view illustrating a condition of a layer thickness of an end of the developing roller in the first embodiment of the present disclosure.

FIG. **4**A is a graph illustrating a layer thickness distribution of the developing roller in the axis direction thereof in the first embodiment of the present disclosure.

FIG. **4**B is a graph illustrating a layer thickness distribution of the developing roller in the axis direction thereof in the first embodiment of the present disclosure.

FIG. **5** is a sectional view of a base member of the developing roller in the first embodiment of the present disclosure.

FIG. **6**A is a sectional view illustrating a state that a flange portion is mounted in a developing roller as a comparative example of the developing roller in the embodiment of the present disclosure.

FIG. **6**B is a sectional view illustrating a state that a flange portion is mounted in the developing roller in the first embodiment of the present disclosure.

FIG. **7** is a sectional view of an end of a developing roller in a second embodiment of the present disclosure.

FIG. **8** is a sectional view of an end of a developing roller in a third embodiment of the present disclosure.

FIG. **9** is an exploded sectional view of an end of a developing roller in a fourth embodiment of the present disclosure.

FIG. **10**A is a schematic diagram illustrating a relationship between the axial length of a photosensitive drum and the axial length of a developing roller in a modified embodiment of the present disclosure.

FIG. **10**B is an enlarged sectional view of an axial end of the photosensitive drum in the modified embodiment of the present disclosure.

DETAILED DESCRIPTION

In the following, embodiments of the present disclosure are described in details, based on the drawings. The present disclosure is applicable to an image forming apparatus using an electrophotography method such as a copying machine, a printer, a facsimile machine, and a complex machine provided with the functions of these machines.

FIG. **1** is a sectional front view illustrating a structure of an image forming apparatus **1** embodying the present disclosure. The image forming apparatus **1** is provided with an apparatus main body **11**. An image forming section **12**, a fixing device **13**, a sheet feeding portion **14**, a sheet discharging portion **15**, and a document reading portion **16** are provided in the apparatus main body **11**.

The apparatus main body **11** is provided with a lower main body **111**, an upper main body **112** disposed above the lower main body **111** to face the lower main body **111**, and a connecting portion **113** disposed between the upper main body **112** and the lower main body **111**. The connecting portion **113** is a structural member for connecting the lower main body **111** and the upper main body **112** in a state that the sheet discharging portion **15** is formed between the lower main body **111** and the upper main body **112**. The connecting portion **113** stands upright from a left portion and a rear portion of the lower main body **111**, and has an L-shape in plan view. The upper main body **112** is supported on the upper end of the connecting portion **113**.

The image forming section **12**, the fixing device **13**, and the sheet feeding portion **14** are provided in the lower main body **111**. The document reading portion **16** is mounted on the upper main body **112**.

The image forming section **12** performs an image forming operation of forming a toner image on a sheet P fed from the sheet feeding portion **14**. The image forming section **12** is provided with a yellow image forming unit **12**Y using yellow toner, a magenta image forming unit **12**M using magenta toner, a cyan image forming unit **12**C using cyan toner, and a black image forming unit **12**Bk using black toner, which are horizontally arranged in this order from upstream toward downstream; an intermediate transfer belt **125** wound around and stretched between rollers including a drive roller **125**A to run endlessly in a sub scanning direction during an image forming operation; a secondary transfer roller **196** which comes into contact with the outer surface of the intermediate transfer belt **125**; and a belt cleaning device **198**.

Each of the image forming units **12**Y, **12**M, **12**C, and **12**Bk of the image forming section **12** is integrally provided with a photosensitive drum **121**, a developing device **122** for supplying toner (a developer) to the photosensitive drum **121**, a toner cartridge (not illustrated) for accommodating toner, a charging device **123**, and a drum cleaning device **127**. Further, an exposure device **124** is horizontally disposed at a position adjacent to and below the developing devices **122** for irradiating the photosensitive drums **121**.

The photosensitive drum **121** has a cylindrical shape, and is rotated around an axis thereof. The photosensitive drum **121** forms an electrostatic latent image on the circumferential surface thereof, and carries a toner image obtained by developing the electrostatic latent image with toner. In the embodiment, the photosensitive drum **121** is a well-known organic (OPC) photosensitive member. A charge generation layer, a charge transport layer, and the like are formed on the surface of the photosensitive drum **121** by the same immersion process as applied to manufacture a developing roller **83** to be described later.

The developing device **122** supplies toner to an electrostatic latent image on the circumferential surface of the photosensitive drum **121**, which is rotated in the arrow direction, for depositing the toner, and forms a toner image in accordance with image data on the circumferential surface of the photosensitive drum **121**. Toner is replenished from the toner cartridge to each of the developing devices **122**, as necessary.

The charging device **123** is provided at a position immediately below each of the photosensitive drums **121**. The charging device **123** uniformly charges the circumferential surface of the photosensitive drum **121**.

The exposure device **124** is provided at a position below the charging devices **123**. The exposure device **124** emits laser light corresponding to each color based on image data input from a computer or a like device, or based on image data acquired in the document reading portion **16** to the circumferential surface of each of the charged photosensitive drums **121** for forming an electrostatic latent image on the circumferential surface of each of the photosensitive drums **121**. The exposure device **124** emits the laser light in accordance with a predetermined exposure light amount in order to form a latent image of a predetermined potential on the photosensitive drum **121**. The drum cleaning device **127** is provided on the left of each of the photosensitive drums **121** to remove the toner residues on the circumferential surface of the photosensitive drum **121** for cleaning the photosensitive drum **121**.

The intermediate transfer belt **125** is an endless belt, and is a soft and conductive belt having a laminate structure constituted of a base layer, an elastic layer, and a coat layer. The intermediate transfer belt **125** is wound around and stretched between substantially horizontally disposed stretching rollers at a position above the image forming section **12**. The stretching rollers include the drive roller **125**A disposed near the fixing device **13**, and configured to drive and rotate the intermediate transfer belt **125**; and a driven roller **125**E disposed horizontally away from the drive roller **125**A by a predetermined distance, and configured to be driven and rotated in association with the intermediate transfer belt **125**. The intermediate transfer belt **125** is driven to circulate clockwise in FIG. **1** when a rotational driving force is applied to the drive roller **125**A.

The secondary transfer roller **196** is electrically connected to a secondary transfer bias application portion (not illustrated). A toner image formed on the intermediate transfer belt **125** is transferred to a sheet P transported from a transport roller pair **192** disposed below the secondary transfer roller **196** when a transfer bias voltage is applied between the secondary transfer roller **196** and the drive roller **125**A. The belt cleaning device **198** is disposed to face the driven roller **125**E on the outside of the driven roller **125**E via the intermediate transfer belt **125**.

The fixing device **13** is provided with a heating roller **132** internally provided with an electric heater such as a halogen lamp, which is a heating source, and a pressing roller **134** disposed to face the heating roller **132**. The fixing device **13** performs a fixing process with respect to a toner image on a sheet P which has undergone a transfer process in the image forming section **12** by transferring heat of the heating roller **132** during a time when the sheet P passes a fixing nip portion between the heating roller **132** and the pressing roller **134**. The sheet P carrying a color image, which has undergone the fixing process, is discharged toward a sheet discharge tray **151** provided at a top portion of the apparatus main body **11** through a sheet discharge transport path **194** extending from an upper portion of the fixing device **13**.

The sheet feeding portion **14** is provided with a manual tray **141** which is openably and closably mounted on the right wall of the apparatus main body **11** in FIG. **1**, and a sheet cassette **142** detachably mounted at a position lower than the exposure device **124** within the apparatus main body **11**. The sheet cassette **142** is capable of accommodating a sheet stack P1 constituted of a number of sheets P. A pickup roller **143** is mounted above the sheet cassette **142**. The pickup roller **143** feeds the uppermost sheet P of the sheet stack P1 accommodated in the sheet cassette **142** toward a sheet transport path **190**. The manual tray **141** is a tray provided at a lower position on the right surface of the lower main body **111** for manually feeding sheets P one by one toward the image forming section **12**.

The sheet transport path **190** extending in up and down directions is formed on the left of the image forming section **12**. A transport roller pair **192** is provided at an appropriate position on the sheet transport path **190**. The transport roller pair **192** transports a sheet P fed from the sheet feeding portion **14** toward a secondary transfer nip portion including the secondary transfer roller **196**.

The sheet discharging portion **15** is formed between the lower main body **111** and the upper main body **112**. The sheet discharging portion **15** is provided with the sheet discharge tray **151** formed on the upper surface of the lower main body **111**. The sheet discharge tray **151** is a tray on which a sheet P carrying a toner image formed in the image forming section **12** is discharged after having undergone a fixing process in the fixing device **13**.

The document reading portion **16** is provided with a contact glass **161** mounted in an opening of the upper surface of the upper main body **112** for placing a document thereon, a document pressing cover **162** which is provided openably and closably for pressing a document placed on the contact glass **161**, and a scanning mechanism **163** for scanning a document placed on the contact glass **161** to read the image of the document. The scanning mechanism **163** optically reads a document image, using an image sensor such as a CCD (Charge Coupled Device) image sensor or a CMOS (Complementary Metal Oxide Semiconductor) image sensor to generate image data. Further, the apparatus main body **11** includes an image processing portion (not illustrated) for generating an image to be processed from the image data

<Configuration of Developing Device>

In this section, the developing device **122** is described in detail. FIG. **2** is a sectional view schematically illustrating an inner structure of the developing device **122** in up and down directions and in left and right directions. The developing device **122** in the embodiment employs a touchdown developing method provided with the developing roller **83** and a magnetic roller **82** to be described later. The developing device **122** includes a developing housing **80** for defining an inner space of the developing device **122**. The developing housing **80** is provided with a developer storage portion **81** for storing a developer containing non-magnetic toner, which is charged at a predetermined polarity, and magnetic carriers. Further, the developing housing **80** is internally provided with the magnetic roller **82** which is disposed above the developer storage portion **81**, the developing roller **83** which is disposed to face the magnetic roller **82** at an obliquely upper position of the magnetic roller **82**, and a developer restraining blade **84** which is disposed to face the magnetic roller **82**. Further, the developing device **122** is provided with a driving portion **962** and a developing bias application portion **88** (bias application portion) (see FIG. **2**).

The developer storage portion **81** includes two developer storage chambers **81***a* and **81***b* adjacent to each other and extending in the length direction of the developing device **122**. The developer storage chambers **81***a* and **81***b* are separated from each other by a partition plate **801** which is integrally formed with the developing housing **80** and extends in the length direction. The developer storage chambers **81***a* and **81***b* are communicated with each other by an unillustrated communication path at both ends of the partition plate **801** in the length direction (axis direction). Screw feeders **85** and **86** for agitating and transporting a developer by rotations around the axes thereof are housed in the developer storage chambers **81***a* and **81***b*, respectively. The screw feeders **85** and **86** are driven and rotated by an unillustrated driving mechanism. The rotating directions of the screw feeders **85** and **86** are set to be opposite to each other. According to this configuration, a developer is circulated and transported between the developer storage chamber **81***a* and the developer storage chamber **81***b*, while being agitated. By the agitation, the toner and the carriers are mixed, and the toner is positively charged, for instance.

The magnetic roller **82** is disposed to extend along the length direction of the developing device **122**. In FIG. **2**, the magnetic roller **82** is driven and rotated clockwise. A fixed-type magnet roll (fixed magnet, not illustrated) is disposed inside the magnetic roller **82**. The magnet roll has a plurality of poles. In the embodiment, the magnet roll has a scooping pole **821**, a restraining pole **822**, and a main pole **823**. The scooping pole **821** faces the developer storage portion **81**. The restraining pole **822** faces the developer restraining blade **84**. The main pole **823** faces the developing roller **83**.

The magnetic roller **82** magnetically scoops (receives) the developer from the developer storage portion **81** to a circumferential surface **82**A of the magnetic roller **82** by a magnetic force of the scooping pole **821**. The magnetic roller **82** magnetically holds the scooped developer on the circumferential surface **82**A as a developer layer (magnetic brush layer). As the magnetic roller **82** is rotated, the developer is transported toward the developer restraining blade **84**.

The developer restraining blade **84** is disposed upstream of the developing roller **83** with respect to the rotating direction of the magnetic roller **82**, and restrains the layer thickness of the developer layer that has been magnetically deposited on the circumferential surface **82**A of the magnetic roller **82**. Further, the developer restraining blade **84** forms a restraining gap G of a predetermined size between the developer restraining blade **84** and the circumferential surface **82**A of the magnetic roller **82**. According to this configuration, a uniform developer layer of a predetermined thickness is formed on the circumferential surface **82**A.

The developing roller **83** is disposed to extend along the length direction of the developing device **122** and in parallel to the magnetic roller **82**. The developing roller **83** is driven and rotated clockwise in FIG. **2**. The developing roller **83** is disposed to face the photosensitive drum **121**. The developing roller **83** has a cylindrical shape, and is rotated around the axis thereof. The developing roller **83** includes a circumferential surface **83**A for receiving toner from the developer layer to carry a toner layer, while rotating in contact with the developer layer held on the circumferential surface **82**A of the magnetic roller **82**. When a developing operation is performed, the developing roller **83** supplies toner of the toner layer to the circumferential surface of the photosensitive drum **121**. In the embodiment, the developing roller **83** is a roller configured such that a resin coat (nylon coat) is coated on the surface of anodized aluminum.

The developing roller **83** and the magnetic roller **82** are driven and rotated by the driving portion **962**. A clearance S of a predetermined size is formed between the circumferential surface **83**A of the developing roller **83** and the circumferential surface **82**A of the magnetic roller **82**. The clearance S is set to 0.3 mm, for instance. The developing roller **83** is disposed to face the photosensitive drum **121** through an opening formed in the developing housing **80**. A clearance of a predetermined size is formed between the circumferential surface **83**A and the circumferential surface of the photosensitive drum **121**. In the embodiment, the clearance is set to 0.12 mm. Further, the developing bias application portion **88** applies a developing bias voltage obtained by superimposing an alternate-current voltage with a direct-current voltage to the magnetic roller **82** and to the developing roller **83**.

The following is an example of developing bias voltages to be applied to the magnetic roller **82** and to the developing roller **83** by the developing bias application portion **88** during a developing operation.

DC voltage Vmag_dc of magnetic roller **82**: 300 V

DC voltage Vslv_dc of developing roller **83**: 50 V

AC voltage (Vpp) Vmag_ac between developing roller **83** and magnetic roller **82**: 1800 V (4.7 kHz)

AC voltage (Vpp) Vslv_ac of developing roller **83**: 1300 V (4.7 kHz)

Duty ratio of AC voltage of developing roller **83**: 45%

Duty ratio of AC voltage between developing roller **83** and magnetic roller **82**: 70%

Potential VL of image portion on photosensitive drum **121**: +20 V

Potential Vo of background portion on photosensitive drum **121**: +230 V

As described above, a high AC voltage is applied between the photosensitive drum **121** and the developing roller **83**, and between the developing roller **83** and the magnetic roller **82**. In particular, toner is supplied from the magnetic roller **82** to the developing roller **83**, and then, toner is supplied from the developing roller **83** to the photosensitive drum **121**. Therefore, as compared with a well-known one component developing device and two-component developing device, a high AC voltage is applied to the developing roller **83** in order to move toner.

Next, the photosensitive drum **121** and the developing roller **83** in a first embodiment of the present disclosure are described in detail, referring to FIG. **3**A to FIG. **6**B. FIG. **3**A is a schematic diagram illustrating a relationship between the axial length of the photosensitive drum **121** and the axial length of the developing roller **83** in the embodiment. FIG. **3**B is a schematic sectional view illustrating a condition of a layer thickness of a coat layer **83**C at an end of the developing roller **83**. FIG. **4**A and FIG. **4**B are graphs illustrating a layer thickness distribution of the coat layer **83**C of the developing roller **83** in the axis direction. FIG. **5** is a sectional view of a sleeve **830** of the developing roller **83**. FIG. **6**A is a sectional view illustrating a state that a flange portion is mounted in a developing roller as a comparative example of the developing roller **83** in the embodiment. FIG. **6**B is a sectional view illustrating a state that a flange portion is mounted in the developing roller **83** in the embodiment.

Referring to FIG. **3**A, in the embodiment, the axial length of the photosensitive drum **121** is set to be longer than the axial length of the developing roller **83**. Therefore, both axial ends of the developing roller **83** face the photosensitive drum **121** in portions L on the inner side of both axial ends of the photosensitive drum **121**. Referring to FIG. **3**B and FIG. **6**B, the developing roller **83** is provided with the sleeve **830** (base member) having a cylindrical shape, and a pair of flange portions **835** to be mounted on both axial ends of the sleeve **830**. The sleeve **830** is made of aluminum. Further, the sleeve **830** is provided with the coat layer **83**C (surface layer) made of resin. The coat layer **83**C is formed by an immersion process to be described later. Further, the flange portion **835** is provided with a flange end portion **835**A and a press-fitting portion **835**B. The flange end portions **835**A expose from both ends of the sleeve **830**. The press-fitting portion **835**B is pressed in the inner periphery of the sleeve **830**. Further, the sleeve **830** is provided with a sleeve middle portion **831** (middle portion), and a sleeve small diameter portion **832** (small diameter portion) (see FIG. **5**). The sleeve middle portion **831** is a portion located at an axially middle portion of the sleeve **830**. On the other hand, the sleeve small diameter portion **832** is a portion which extends from an axial end of the sleeve **830** axially inward by a predetermined length, and has an outer diameter smaller than the sleeve middle portion **831**. Specifically, in FIG. **5**, the outer diameter LA of the sleeve middle portion **831** is set to be larger than the outer diameter LB of the sleeve small diameter portion **832**. The sleeve small diameter portion **832** is disposed on the axially outer side of an image forming area on the photosensitive drum **121**.

The coat layer **83**C of the sleeve **830** is manufactured by the following steps. First of all, anodized aluminum is coated on the outer surface of the sleeve **830** to form an anodized aluminum layer (oxidized layer) of 10 μm in thickness. Forming an oxidized layer on the sleeve **830** made of aluminum makes it possible to increase the adhesion force of the coat layer **83**C with respect to a base member. As a result of this treatment, peeling off of the coat layer **83**C is prevented. Thereafter, the surface of the sleeve **830**, specifically, the surface of the anodized aluminum layer is heat treated at 120° C. for 10 minutes or longer. The heat treatment is performed to intentionally cause cracks in the sleeve **830** in advance for preventing generation of cracks in a drying step of the coat layer **83**C. The time of the heat treatment is set in advance. For instance, the time of the heat treatment is set to be equal or longer than the time required for the drying step. The heat treatment is always performed at a predetermined temperature for a predetermined time. Cracks of a substantially fixed quantity are generated in all the sleeves **830** which have undergone the heat treatment. A process of forming the coat layer **83**C is performed after the heat treatment. Specifically, a mixed solution is prepared by mixing nylon resin as a binder resin, titanium oxide as a conductive agent, and methanol **800** (parts by weight) as a dispersant medium with zirconia beads of 1.0 mm in diameter in a ball mill for about 48 hours. The sleeve **830** treated with anodized aluminum is immersed in the mixed solution for a predetermined time, and then is taken out from the mixed solution. The sleeve **830** is dried in a high-temperature environment of 130° C. for 10 minutes. The sleeve **830** is immersed in the mixed solution in such a manner that the axis direction of the sleeve **830** having a cylindrical shape is aligned with a vertical direction. As a result of the immersion operation, a sleeve **830** coated with a coat layer **830**C of a thickness in the range of from 2 μm to 11 μm is manufactured. As described above, cracks are generated in the anodized aluminum layer in advance by the heat treatment, before the coat layer **83**C is coated. This makes it possible to prevent local distribution of a conductive agent contained in the coat layer **83**C due to the influence of a convection current, which may be generated inside the coat layer **83**C at the time of drying the coat layer **83**C. Thus, it is possible to form a coat layer **83**C in which a conductive agent is uniformly distributed.

On the other hand, when a coat layer **83**C is formed by the aforementioned immersion process, the mixed solution adhered to the surface of a sleeve **830** is likely to droop due to the influence of gravitational force at the time of taking out the sleeve **830**. As a result, when an immersion operation is performed, a coat layer **83**C having a large thickness, as compared with an axially middle portion of the sleeve **830**, may be formed on the surface of a lower end of the sleeve **830**. In particular, a thick portion **83C1** (see FIG. **3**B) where the thickness of the coat layer **83**C is large is likely to be formed at a lower end of the sleeve **830**. Further, when an immersion operation is performed, a thin coat layer **83**C, as compared with an axially middle portion of the sleeve **830**, is likely to be formed on the surface of an upper end of the sleeve **830**.

FIG. **4**A illustrates a layer thickness distribution of the coat layer **83**C formed on a lower end of the sleeve **830**. On the other hand, FIG. **4**B illustrates a layer thickness distribution of the coat layer **83**C formed on an upper end of the sleeve **830**. In both of the drawings, the horizontal axis denotes a distance from an end of the sleeve **830**, and the vertical axis denotes a layer thickness at each position in the axis direction, as a difference with respect to an average layer thickness of the coat layer **83**C. As illustrated in FIG. **4**A and FIG. **4**B, the length of the upper end where the coat layer **83**C has a small thickness is longer than the length of the lower end where the coat layer **83**C has a large thickness. Further, the maximum amount (3 μm) of reduction of the layer thickness of the coat layer **83**C at the upper end is approximate to the maximum amount (3.5 μm) of increase of the layer thickness of the coat layer **83**C at the lower end.

Further, as described above, in the embodiment, the flange portions **835** are mounted in the sleeve **830**. FIG. **6**A is a schematic sectional view of a case, in which the sleeve small diameter portion **832** (see FIG. **6**B) is not formed on a sleeve **830** in a substantially same configuration as in the embodiment. When the press-fitting portion **835**B of the flange portion **835** is pressed in the end of the sleeve **830**, as illustrated in FIG. **6**A, the outer diameter of the end of the sleeve **830** is slightly expanded. As a result of the above operation, the end of the coat layer **83**C is expanded radially outward. Therefore, the gap between the photosensitive drum **121** and the developing roller **83** is partially reduced. This may cause voltage leakage when a developing bias voltage (AC voltage) is applied. Further, as described above, when the thick portion **83**C**1** is formed at the lower end of the coat layer **83**C, the gap between the photosensitive drum **121** and the developing roller **83** may be further reduced.

In order to overcome the aforementioned drawbacks, the developing roller **83** in the embodiment is provided with the sleeve small diameter portion **832** as described above. Referring to FIG. **6**B, the sleeve small diameter portion **832** is formed by cutting the lower end of the sleeve **830** in advance, before the coat layer **83**C is formed on the sleeve **830** by an immersion process. Forming the coat layer **83**C after formation of the sleeve small diameter portion **832** as described above makes it possible to form the coat layer **83**C along a step between the sleeve middle portion **831** and the sleeve small diameter portion **832**. In this case, the thick portion **83**C**1** is slightly formed at the lower end of the coat layer **83**C. As illustrated in FIG. **6**B, when the press-fitting portion **835**B of the flange portion **835** is pressed in the end of the sleeve **830**, the sleeve small diameter portion **832** is deformed to radially outwardly expand. However, the sleeve small diameter portion **832** has a smaller diameter than the sleeve middle portion **831**. Therefore, the surface of the thick portion **83**C**1** is substantially axially flush with the surface of the coat layer **83**C on the sleeve middle portion **831**. This makes it possible to prevent partial reduction of the gap between the developing roller **83** and the photosensitive drum **121** at the axial end of the developing roller **83**. This is advantageous in preventing voltage leakage. In particular, the sleeve small diameter portion **832** is formed on the developing roller **83** whose axial length is shorter between the photosensitive drum **121** and the developing roller **83**. Therefore, this is further advantageous in preventing voltage leakage at the axial end of the developing roller **83**. It is possible to set the outer diameter of the sleeve small diameter portion **832** so that the outer diameter of the thick portion **83**C**1** after the pressing operation is smaller than the outer diameter of the coat layer **83**C on the sleeve middle portion **831** in order to prevent local voltage leakage at the thick portion **83**C**1**.

Further, in the embodiment, referring to FIG. **6**B, the axial length L**1** of the sleeve small diameter portion **832** is set to be longer than the axial length L**2** of the press-fitting portion **835**B. This is further advantageous in preventing partial reduction of the gap between the developing roller **83** and the photosensitive drum **121** due to a pressing operation of the press-fitting portion **835**B.

Furthermore, in the embodiment, the developing device **122** is a touchdown developing device provided with the magnetic roller **82** and the developing roller **83**. As described above, even in a configuration in which a large AC voltage is applied to the developing roller **83**, it is possible to stably prevent voltage leakage by the existence of the sleeve small diameter portion **832**.

Next, a developing roller **83**P in a second embodiment of the present disclosure is described referring to FIG. **7**. FIG. **7** is a sectional view of an end of the developing roller **83**P. In the second embodiment, the axial length of the developing roller **83**P is also set to be shorter than the axial length of an unillustrated photosensitive drum. A sleeve small diameter portion **832**P (small diameter portion) is formed at an end of a sleeve **830**P (base member) of the developing roller **83**P. Unlike the developing roller **83** in the first embodiment, the developing roller **83**P carries magnetized toner on the circumferential surface thereof. In view of the above, as well as the magnetic roller **82** described in the first embodiment, the developing roller **83**P is internally provided with a fixed magnet MG extending in the axis direction of the developing roller **83**P. The axial length of the fixed magnet MG is set to be smaller than the axial length of the developing roller **83**P. Further, an image forming area IA where an electrostatic latent image is formed on the circumferential surface of the photosensitive drum is set in an area of a size shorter than the axial length of the fixed magnet MG.

As illustrated in FIG. **7**, in the second embodiment, a sleeve small diameter portion **832**P is located on the axially outer side of the image forming area IA on the photosensitive drum. Therefore, the image forming area IA is included in a sleeve middle portion **831**P. According to this configuration, even when the gap between the developing roller **83**P and the photosensitive drum is partially varied in the periphery of the sleeve small diameter portion **832**P, it is possible to stably and precisely perform a developing operation of developing an electrostatic latent image on the photosensitive drum using a developer with a certain gap. Further, the sleeve small diameter portion **832**P is disposed on the axially outer side of the fixed magnet MG. This configuration makes it possible to prevent magnetized toner from adhering to the periphery of the sleeve small diameter portion **832**P. This is advantageous in stably implementing a developing operation of developing an electrostatic latent image on the photosensitive drum using toner. Furthermore, magnetized toner is less likely to adhere to the sleeve small diameter portion **832**P. Therefore, it is possible to prevent voltage leakage by way of magnetized toner. Also in the second embodiment, a coat layer may be formed on the circumferential surface of the sleeve **830**P by an immersion process.

Next, a developing roller **83**Q in a third embodiment of the present disclosure is described referring to FIG. **8**. FIG. **8** is a sectional view of an end of the developing roller **83**Q. In the third embodiment, the axial length of the developing roller **83**Q is also set to be shorter than the axial length of an unillustrated photosensitive drum. A sleeve small diameter portion **832**Q (small diameter portion) is formed on an end of a sleeve **830**Q (base member) of the developing roller **83**Q. The developing roller **83**Q is provided with a flange portion **835**Q that includes a flange end portion **835**AQ and a press fitting portion **435**BQ. The press-fitting portion **835**BQ of the flange portion **835**Q is pressed in an end of the sleeve **830**Q. Unlike the developing roller **83** in the first embodiment, the sleeve **830**Q of the developing roller **83**Q is provided with an in-low portion **836** (press-fitted portion). The in-low portion **836** is a portion whose inner diameter is set to be large at an axial end of the sleeve **830**Q. The press-fitting portion **835**BQ of the flange portion **835**Q is pressed in the in-low portion **836**. The axial length L**3** of the sleeve small diameter portion **832**Q is set to be longer than the axial length L**4** of the in-low portion **836**.

Providing the in-low portion **836** in advance in the sleeve **830**Q makes it easy to implement a pressing operation of the press-fitting portion **835**BQ. The in-low portion **836**, however, has a relatively small thickness, as compared with the other portion, and is likely to be deformed. In view of the above, the sleeve small diameter portion **832**Q is formed in a large area, as compared with the in-low portion **836**. Therefore, even when the sleeve small diameter portion **832**Q located on the outer side of the in-low portion **836** is radially expanded due to a pressing operation of the press-fitting portion **835**BQ, it is possible to prevent the sleeve small diameter portion **832**Q from bulging toward the photosensitive drum with respect to the sleeve middle portion **831**Q. Thus, the above configuration is advantageous in preventing partial reduction of the gap between the developing roller **83**Q and the photosensitive drum, and in preventing voltage leakage.

Next, a developing roller **83**R in a fourth embodiment of the present disclosure is described referring to FIG. **9**. FIG. **9** is an exploded sectional view of an end of the developing roller **83**R. In the fourth embodiment, the axial length of the developing roller **83**R is also set to be shorter than the axial length of an unillustrated photosensitive drum. A sleeve small diameter portion **832**R (small diameter portion) is formed at an end of a sleeve **830**R (base member) of the developing roller **83**R. The developing roller **83**R is provided with a flange portion **835**R constituted of a flange end portion **835**AR and a press-fitting portion **835**BR. The press-fitting portion **835**BR of the flange portion **835**R is pressed in the end of the sleeve **830**R. Further, a coat layer **83**CR (surface layer) is formed on the surface of the sleeve **830**R in advance by an immersion process. The coat layer **83**CR is formed to extend along the shape of a step between a sleeve middle portion **831**R and the sleeve small diameter portion **832**R.

In the fourth embodiment, the outer diameter L**5** of the press-fitting portion **835**BR is set to be equal to or larger than the inner diameter L**6** of the axial end of the sleeve **830**R. Therefore, when the flange portion **835**R is mounted in the sleeve **830**R, the press-fitting portion **835**BR is pressed in the sleeve **830**R, while expanding the inner periphery of the sleeve **830**R by a pressing operation. This makes it possible to prevent disengagement of the flange portion **835**R after the pressing operation. However, as described above, when the flange portion **835**R is mounted, the sleeve small diameter portion **832**R of the sleeve **830**R is likely to expand. In view of the above, in the fourth embodiment, the value obtained by doubling the difference (L**7**) between the radius of the sleeve small diameter portion **832**R and the radius of the axially middle portion of the sleeve **830**R is set to be larger than the difference between the outer diameter of the press-fitting portion **835**BR and the inner diameter of the axial end of the sleeve **830**R, in other words, the value (L**5**-L**6**) in FIG. **9**. According to this configuration, the amount of increase of the sleeve small diameter portion **832**R accompanied by mounting of the flange portion **835**R is smaller than the predetermined amount of reduction of the sleeve small diameter portion **832**R with respect to the sleeve middle portion **831**R. This is further advantageous in preventing partial reduction of the gap between the developing roller **83**R and the photosensitive drum due to a pressing operation of the press-fitting portion **835**BR.

Further, in the fourth embodiment, the value obtained by doubling the thickness (L**8**) of the coat layer **83**CR is set to be larger than the difference between the outer diameter of the press-fitting portion **835**BR and the inner diameter of the axial end of the sleeve **830**R, in other words, the value (L**5**-L**6**) in FIG. **9**. Specifically, the thickness of the coat layer **83**CR is set to be larger than one-half of the difference between the outer diameter of the press-fitting portion **835**BR and the inner diameter of the axial end of the sleeve **830**R. This makes it possible to prevent the axial end of the coat layer **83**CR from bulging radially outward with respect to the axially middle portion of the coat layer **83**CR.

Furthermore, in the foregoing embodiments, toner is supplied from the magnetic roller **82** (**82**P, **82**Q, **82**R) to the developing roller **83** (**83**P, **83**Q, **83**R), and then, toner is supplied from the developing roller **83** (**83**P, **83**Q, **83**R) to the photosensitive drum **121**. According to this configuration, as compared with a well-known one-component developing device and two-component developing device, a high AC voltage is applied to the developing roller **83** (**83**P, **83**Q, **83**R) in order to move toner. However, the developing roller **83** (**83**P, **83**Q, **83**R) is provided with the sleeve small diameter portion **832** (**832**P, **832**Q, **832**R). Therefore, it is possible to prevent partial reduction of the gap between the developing roller **83** (**83**P, **83**Q, **83**R) and the photosensitive drum **121**, and to prevent voltage leakage at the axial end of the developing roller **83** (**83**P, **83**Q, **83**R).

In the foregoing, the image forming apparatus **1** according to each of the embodiments of the present disclosure has been described. The present disclosure is not limited to the above. For instance, the following modified embodiment may be applied.

(1) In the foregoing embodiments, the sleeve small diameter portion **832** (**832**P, **832**Q, **832**R) is provided at the axial end of the developing roller **83** (**83**P, **83**Q, **83**R). The present disclosure is not limited to the above. FIG. **10**A is a schematic diagram illustrating a relationship between the axial length of a photosensitive drum **121**S and the axial length of a developing roller **83**S in the modified embodiment of the present disclosure. FIG. **10**B is an enlarged sectional view of an axial end of the photosensitive drum **121**S. In the modified embodiment, the axial length of the photosensitive drum **121**S is set to be shorter than the axial length of the developing roller **83**S, and the photosensitive drum **121**S is provided with a drum small diameter portion **121**H (small diameter portion). The photosensitive drum **121**S is provided with a drum member **121**G (base member) made of aluminum. A flange portion **121**F is mounted in an end of the drum member **121**G. Further, a functional layer **121**C (a charge generation layer, a charge transport layer) (surface layer) is formed on the surface of the drum member **121**G by the same immersion process as applied to formation of the coat layer **83**C of the developing roller **83** in the first embodiment. The functional layer **121**C is formed to extend along the shape of the drum member **121**G provided with the drum small diameter portion **121**H. A thick portion **121**C**1** bulges from an axial end of the functional layer **121**C.

Also in this configuration, providing the drum small diameter portion **121**H on the drum member **121**G in advance makes it possible to prevent partial reduction of the gap between the developing roller **83**S and the photosensitive drum **121**S at an axial end of the photosensitive drum **121**S due to formation of the thick portion **121**C**1** or due to a pressing operation of the flange portion **121**F. Alternatively, a portion devoid of the functional layer **121**C may be formed at an axial end of the drum member **121**G of the photosensitive drum **121**S.

(2) In the first embodiment, the developing roller **83** is provided with the coat layer **83**C, and the flange portions **835** are mounted in the sleeve **830** of the developing roller **83**. The present disclosure is not limited to the above. The developing roller **83** may not be provided with the coat layer **83**C, and the flange portions **835** may be mounted in the developing roller **83**. Conversely to the above, the developing roller **83** may be provided with the coat layer **83**C, and the flange portions **835** may not be mounted in the developing roller **83**. The same idea is applied to a configuration, in which a small diameter portion is provided on the photosensitive drum **121**.

Although the present disclosure has been fully described by way of example with reference to the accompanying drawings, it is to be understood that various changes and modifications will be apparent to those skilled in the art. Therefore, unless otherwise such changes and modifications depart from the scope of the present disclosure hereinafter defined, they should be construed as being included therein.

The invention claimed is:

1. A developing device for supplying a developer to a photosensitive drum, which has a cylindrical shape, and is rotatable around an axis thereof for forming an electrostatic latent image on a circumferential surface thereof, comprising:

a developing roller disposed to face the photosensitive drum, the developing roller having a cylindrical shape, and being rotatable around an axis thereof for carrying a developer on a circumferential surface thereof, the developing roller including a cylindrical base member and a flange portion to be mounted in an axial end of the base member, the flange portion having a press-fitting portion to be pressed in an inner periphery of the base member, wherein

the developing roller is provided with a small diameter portion formed at the axial end of the base member, the small diameter portion being a part of the circumferential surface of the developing roller, the small diameter portion extending from an axial end of the developing roller axially inward by a predetermined length and an axial length of the small diameter portion being longer than an axial length of the press-fitting portion, the small diameter portion having an outer diameter smaller than an axially middle portion of the developing roller.

2. The developing device according to claim **1**, wherein

an axial length of the developing roller is set to be shorter than an axial length of the photosensitive drum.

3. The developing device according to claim **1**, wherein

the developing roller further includes a press-fitted portion with an inner diameter is set to be large at the axial end of the base member so that the press-fitting portion is pressed in the press-fitted portion, and

the axial length of the small diameter portion is set to be longer than the axial length of the press-fitted portion.

4. The developing device according to claim **1**, wherein

an outer diameter of the press-fitting portion is set to be equal to or larger than an inner diameter of the axial end of the base member, and

a difference between the outer diameter of the small diameter portion and an outer diameter of the axially middle portion of the base member is set to be larger than a difference between the outer diameter of the press-fitting portion and the inner diameter of the axial end of the base member.

5. The developing device according to claim **1**, wherein

the small diameter portion is disposed on the circumferential surface of the developing roller on an axially outer side of an image forming area on the circumferential surface of the photosensitive drum where the electrostatic latent image is formed.

6. The developing device according to claim **1**, wherein

the developing roller includes a fixed magnet extending axially inward,

an axial length of the fixed magnet is set to be smaller than an axial length of the developing roller, and

the small diameter portion is disposed on an axial outer side of the fixed magnet.

7. An image forming apparatus, comprising:

the developing device of claim **1**; and

the photosensitive drum to which the developer is supplied from the developing roller.

8. The image forming apparatus according to claim **7**, further comprising:

a bias voltage application portion, wherein

the developing roller carries toner as the developer on the circumferential surface thereof,

the developing device further includes a magnetic roller disposed away from the developing roller by a predetermined distance, the magnetic roller internally including an axially extending fixed magnet, and being rotatable while carrying the toner and carriers on a circumferential surface of the magnetic roller; and

the bias voltage application portion applies a developing bias voltage to the developing roller and to the magnetic roller, the developing bias voltage being obtained by superimposing an alternate-current voltage with a direct-current voltage.

9. A developing device for supplying a developer to a photosensitive drum, which has a cylindrical shape, and is rotatable around an axis thereof for forming an electrostatic latent image on a circumferential surface thereof, comprising:

a developing roller disposed to face the photosensitive drum, the developing roller having a cylindrical shape, and being rotatable around an axis thereof for carrying a developer on a circumferential surface thereof, the developing roller including a cylindrical base member and a flange portion to be mounted in an axial end of the base member, the flange portion has a press-fitting portion to be pressed in an inner periphery of the base member, wherein

the developing roller is provided with a small diameter portion, the small diameter portion being a part of the circumferential surface of the developing roller, the small diameter portion extending from an axial end of the developing roller axially inward by a predetermined length, the small diameter portion having an outer diameter smaller than an axially middle portion of the developing roller,

the developing roller is provided with a surface layer to be formed by an immersion process of immersing the base member in such a manner that an axial direction of the developing roller is aligned with a vertical direction, and

the small diameter portion is formed in advance on a lower end of the base member before the immersion process is applied.

10. A developing device for supplying a developer to a photosensitive drum, which has a cylindrical shape, and is rotatable around an axis thereof for forming an electrostatic latent image on a circumferential surface thereof, comprising:

a developing roller disposed to face the photosensitive drum, the developing roller having a cylindrical shape, and being rotatable around an axis thereof for carrying a developer on a circumferential surface thereof, the developing roller including a cylindrical base member and a flange portion to be mounted in an axial end of the base member, the flange portion has a press-fitting portion to be pressed in an inner periphery of the base member, wherein

the developing roller is provided with a small diameter portion, the small diameter portion being a part of the circumferential surface of the developing roller, the small diameter portion extending from an axial end of the developing roller axially inward by a predetermined length, the small diameter portion having an outer diameter smaller than an axially middle portion of the developing roller,

the developing roller is provided with a surface layer to be formed by an immersion process of immersing the base member in such a manner that an axial direction of the developing roller is aligned with a vertical direction,

an outer diameter of the press-fitting portion is set to be equal to or larger than an inner diameter of an axial end of the base member, and

a thickness of the surface layer is set to be larger than one-half of a difference between the outer diameter of the press-fitting portion and the inner diameter of the axial end of the base member.

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